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SITE REQUIREMENTS and YIELD of PAPER BIRCH in NORTHERN WISCONSIN

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The initial phase of the project was completed in 1958 with the publication of site index curves for paper birch in northern Wisconsin as Lake States Forest Experiment Station Technical Note 541. This Station Paper constitutes the final report.

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Cover picture: A pure stand of paper birch. Stands such as these have the potential for producing a high proportion of saw logs and veneer bolts.

Site Requirements and Yield of Paper Birch In Northern Wisconsin

by

John H. Cooley [1]

INTRODUCTION

Paper birch (*Betula papyrifera* Marsh.) as a type and as a species has not been subjected to a great deal of detailed research. Dana (1909) made a comprehensive study in the Northeast and published yield data, volume tables, and generalized management recommendations. Kittredge and Gevorkiantz (1929) presented yield data for heavily stocked stands in the Lake States, based on the measurement of 38 relatively pure stands. Plonski (1956), working in Ontario, developed a comprehensive yield table for paper birch, based on 59 temporary plots. Hutnik and Cunningham (1960) have summarized the available information concerning the silvical characteristics of the species.

In 1956 a study was undertaken to provide forest managers with information on site requirements and yield that would be particularly applicable to stands found in northern Wisconsin. This paper presents the results of that study and includes some preliminary suggestions for the management of paper birch.

The great majority of the data were collected where the Cary and Mankato advances of the Wisconsin ice sheet were the principal agent of land formation. Ground and end moraines cover most of the area, with a few glacial lake deposits near Lake Superior in the northwest and Lake Michigan in the east. Soils are generally deep glacial drift ranging from coarse gravel to fine silt loam. Loamy soils are usually quite rocky. The Door Peninsula in eastern Wisconsin is peculiar in that it is underlain with Niagara limestone. In this area, soils are quite often very shallow, and in some places there is less than a foot of soil over fragmented bedrock.

Average annual precipitation in the area covered by this study is fairly uniform at 30 inches. The northwest averages only 28 inches while the central part averages 32. Average January temperatures range from 10° F. in an east-west belt through the northwest and north central part of Wisconsin to 18° F. near Lake Michigan. Average July temperatures are more uniform, ranging from a low of 66° F. in the extreme northwest and north central parts of the state to a high of 68° F. throughout the rest of the study area.

Average number of days without killing frost clearly shows the effect of Lake Superior and Lake Michigan. In the northwest there is a narrow belt with an average of 140 days without killing frost. In northeast Vilas County the frost-free period averages only 90 days, but on Door Peninsula to the northeast it increases to between 150 and 160 days.

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[1] *The author is Research Forester with the Lake States Forest Experiment Station. The research was done at the Station's Northern Hardwoods Project, Marquette, Mich.*

PROCEDURE •

The study was designed to cover the full range of site conditions on which paper birch occurs in northern Wisconsin. To this end the sampling plan was based on various soil and topographic classes. It became apparent during the early stages of the fieldwork that close adherence to this plan would not provide adequate data for determination of yield; therefore age and total height actually were the major determinants in the selection of most of the plots. The result was a preponderance of plots on light sandy soils in Oneida, Vilas, and Forest Counties where pure stands are most common. Enough other plots were taken to determine the comparability of this area with the remainder of northern Wisconsin. Conditions not commonly found in the three counties were sampled wherever they occurred.

All sample plots were located in fully stocked, undisturbed stands. Stands were considered undisturbed if there was no evidence of cutting and no extensive mortality in the overstory. No samples were taken in stands where the trees in the overstory had exceptionally heavy limbs or short clear length. Stands were not rejected because of scattered mortality, but openings in the crown canopy were avoided when selecting sample plot or sample tree locations.

Considerably more data were collected in pure birch stands than in mixed stands, and sampling techniques were different.

In stands that were almost exclusively paper birch, temporary sample plots were laid out to include a minimum of 50 and a maximum of 100 dominant and codominant trees. Depending on the spacing between trees, plots ranged from 1/10 to ¼ of an acre. On all plots, all trees 4.6 inches d.b.h. and over were tallied by species, d.b.h., crown class, number of 8-foot bolts to an estimated 4-inch top d.i.b., and number of 16-foot logs to an estimated 10-inch top d.i.b. On most of the plots all trees between 0.6 and 4.5 inches d.b.h. were tallied by species, d.b.h., and crown class. Occasionally stands were encountered that had a dense sapling understory of some species other than paper birch. In these two-storied stands, understory trees were sampled only on a subplot centered within the main plot. In the analysis of volume data, plots were rejected if paper birch made up less than 80 percent of the basal area in dominant and codominant trees.

On each plot total heights were measured and annual rings counted on the five dominant or codominant trees closest to the center of the sample plot. If the ring counts indicated an age range greater than 10 years or any periods of suppressed growth lasting more than 5 years, the plot was not included in the analysis. For the plots that were used in the analysis, site index was determined from the curves shown in figure 1 (Cooley 1958).

In mixed stands that met the stocking and age distribution standards set for pure stands, only site index was determined. Although no specific limits were set on the area occupied by sample trees, usually five dominant or codominant trees were selected within 25 feet of each other. Ring counts were made on the trees competing with the sample trees to make sure that all overstory trees were in the same 10-year age class. The procedure for determining site index for paper birch was identical to that used in pure stands. No volume data were taken in mixed stands.

Classification of soils on the plots was based on sampling in predetermined zones rather than detailed profile analysis. On 23 preliminary plots, soil pits were dug to establish zones for sampling. This preliminary work indicated that the upper 6 inches usually included the bulk of the A horizon and the first 36 inches included most of the rooting zone. Soil sampling procedures were therefore established to determine the average characteristics of the soil within these zones. In addition, the soil below the 36-inch level was sampled to a depth of 60 inches wherever the presence of numerous rocks did not limit penetration with a soil sampler.

Two soil sampling points were selected in the vicinity of each group of sample trees. If soil samples from these two appeared to be quite uniform they were considered adequate. If distinct variations appeared, four or more sampling points were used to determine the extent and importance of this variation. Soil from all sampling holes was combined to make a composite sample from each zone.

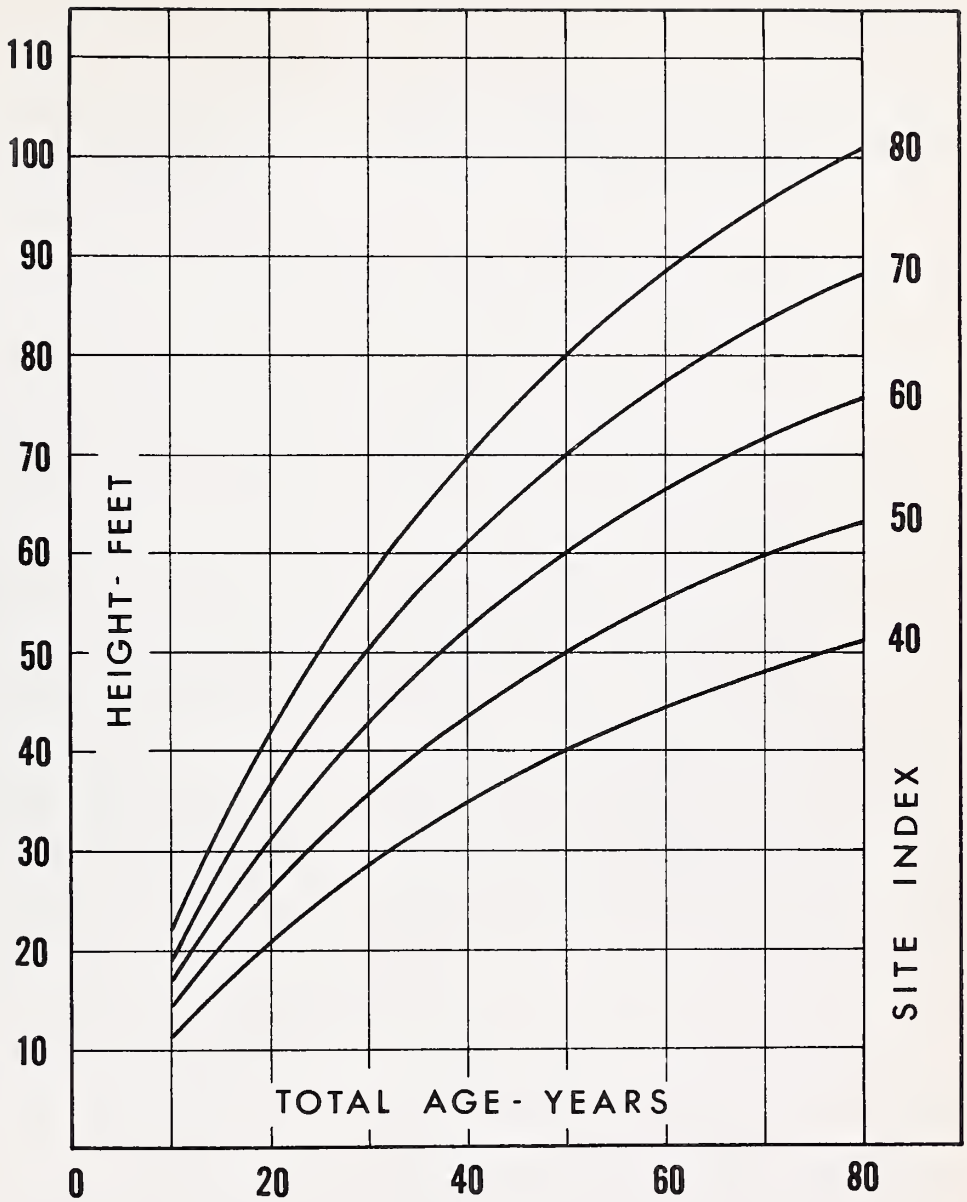

FIGURE 1. — Site index graph for paper birch in northern Wisconsin.

Percent silt-plus-clay was determined with a Cenco-Wilde test kit and soil pH with a LaMotte-Morgan soil reaction set. Soil type was determined when possible, and soil was classified as dry, moist, or wet according to the observer's best estimate of normal soil moisture condition during the growing season. Other soil factors noted were:

1. Depth to bedrock if within the sampling zone.
2. Depth to water table if within the sampling zone.
3. Depth to, and kind of, any noticeable indurated or cemented layer.
4. Depth to, and color of, mottling.
5. Thickness and color of the A horizon.

Stoniness of the upper 36 inches of soil was determined by weighing about 10 pounds of the composite sample from the 0- to 36-inch zone, sifting the soil through a ¼-inch mesh screen, and reweighing the stones. The sampling auger seldom picked up stones more than 3 inches in any dimension, so stones of this size were not included in this

determination. They were noted as being abundant, occasional, or lacking in the 0- to 36-inch zone.

The aspect of each plot was classified on an eight-point system (N, NE, E, SE, etc.). The percent and length of slope were measured and the position of the plot noted relative to breaks in the topography. Surface drainage was classified as poor, fair, or good on the basis of the plot's location in the general drainage pattern. An attempt was made to classify the former cover type and the fire and logging history on the basis of existing evidence, but these classifications were often questionable.

OCCURRENCE OF PAPER BIRCH IN NORTHERN WISCONSIN

Although the methods used in this study did not ensure sampling of each age class in proportion to its frequency of occurrence, preliminary age determinations were made in a great many stands in an attempt to obtain data over the entire age range of the species. Very few fully stocked pure stands less than 30 years old or more than 50 years old were encountered. Stands between these ages were numerous throughout the study area, and stands of a single age class often extended over several hundred acres. Pure stands more than 50 years old were very scarce, and single age classes were limited to relatively small areas. Pure stands less than 30 years old were generally poorly stocked, consisting of scattered clumps of stump sprouts. Occasional groups of young trees of seedling origin were encountered along old skid trails, cut banks, and other areas where mineral soil had been exposed in logging operations.

This distribution indicates that most of the fully stocked paper birch stands in northern Wisconsin originated during the time when wildfires commonly followed logging operations. Before this, some stands probably became established when fire or other natural disturbances destroyed existing cover and exposed mineral soil. Usually these disturbances were not as extensive as the fires that followed logging. Since the beginning of effective fire control, scattered paper birch regeneration has become established as a result of soil disturbance incidental to logging operations.

Paper birch frequently occurs in mixture with both trembling aspen (*Populus tremuloides* Michx.) and largetooth aspen (*P. grandidentata* Michx.). In these stands the birch and aspen are usually the same age, but birch crowns occupy an intermediate position. In other mixed stands, birch is most likely to be at least as tall as the trees of other species, with more tolerant trees occurring as an understory. Occasionally intermediate or suppressed paper birch may be found in natural red pine (*Pinus resinosa* Ait.) or white pine (*P. strobus* L.) stands.

In fully stocked stands, either mixed or pure, birch prunes itself readily and develops a clean bole with little taper. Scattered individuals, however, are likely to develop large crowns which limit merchantable length. General observations of many stands that have been partially cut indicate that exposed trees have a tendency to deteriorate. The younger trees will usually survive when they are exposed, but lack of side competition encourages the development of heavy limbs. Top-dying is prevalent in trees that are exposed when they are nearly mature.

Excessive exposure is more of a problem in stands that are predominantly birch or birch and aspen than in mixed stands where other species usually replace mortality in the overstory, thus helping to maintain a continuous crown canopy. On the whole, paper birch growing in association with hardwoods other than aspen seems to have the best quality potential and be most adaptable to management on a relatively long rotation.

ANALYSIS OF SITE FACTOR DATA •

It was necessary to utilize a combination of techniques in the analysis of site factor data because of the heterogeneous and discontinuous nature of many of the independent variables. First all plots were ranked according to site index. Inspection showed that many of the plots with low site indices, but few of those with high site indices were associated with slopes of 10 percent or more. This factor was then used to separate the plots into two groups and the difference between the mean site index of the two groups was tested for significance.

Following a similar procedure with each variable, groups were subdivided to reduce the variation of site indices. A difference between means that was significant at the 95-percent level was considered sufficient evidence that the variable being tested bore a significant relationship to site index. If a variable was so poorly represented within any one group that a "t" test was not applicable, the appearance of a consistent and logical trend was considered adequate proof of significance. In the final plot groupings, site factors that could be easily evaluated in the field were used whenever possible. Tables 1 and 2 show the number of plots, the mean site index, and the standard deviation where applicable, in each plot group. Each group is assigned an area class which is related to the suggested silvicultural prescriptions outlined in a later section of this report.

Level and Rolling Terrain

Table 1 includes all the plots that were on or adjacent to slopes of less than 10 percent, or slopes greater than 10 percent but with elevation changes of less than 15 feet. The mean site index of the 56 plots in this terrain class was 58 feet with a range of 40 to 85 feet in the individual plot site indices. Within this group, plots with 10.5 percent or less silt-plus-clay in the first 6 inches of mineral soil averaged five site index units lower than those having 10.6 percent silt-plus-clay or more. In the heavier soils where mottling was found in the first 48 inches of soil, the mean site index was 10 feet higher than it was where no mottling was found. In the lighter soils the same relationship existed but of a smaller magnitude.

Four plots were found in this terrain class where water apparently stood on the surface for a significant length of time during the growing

TABLE 1. — *Site index of plots on or adjacent to slopes of less than 10 percent or slopes of greater than 10 percent that resulted in elevation differences of less than 15 feet*

Silt plus clay in first 6 inches of mineral soil (percent)	Surface drainage	Plots	Mean site index	Standard deviation	Area class[1]
		No.	Feet	Feet	
	NO MOTTLING IN FIRST 48 INCHES				
10.5 or less	Poor[2]	0	(3)	(3)	I
	Medium to good	9	52.12	±4.93	II
10.6 or more	Poor[2]	2	43.66	(4)	I
	Medium to good	21	59.34	±6.59	II
	MOTTLING PRESENT IN FIRST 48 INCHES				
10.5 or less	Poor[2]	2	44.20	(4)	I
	Medium to good	6	57.45	±6.77	II
10.6 or more	Poor[2]	0	(3)	(3)	I
	Medium to good	16	64.21	±7.22	III

1 *Area classes and their application are discussed in the section dealing with "Silvicultural Prescriptions" starting on page 8.*
2 *Water standing on the surface for a significant length of time during the growing season.*
3 *Alhough no plots were encountered with this combination of characteristics it was assumed that poor drainage would affect this site adversely as it did in other situations.*
4 *Number of plots insufficient to compute a standard deviation.*

TABLE 2. — *Site index of plots on or adjacent to slopes of 10 percent or more that resulted in elevation differences of 15 feet or more*

Silt plus clay in first 6 inches of mineral soil (percent)	Slope position	Depth to bedrock	Plots	Mean site index	Standard deviation	Area class[1]
		Inches	No.	Feet	Feet	
		25 PERCENT SLOPE OR LESS				
5.5 or less	(3)	(3)	4	47.13	(2)	I
5.6 or more	Ridgetops and slopes	(3)	13	53.13	±11.35	II
	Flats	12 or less	0	(4)	(2)	I
		More than 12	8	58.13	±7.04	II
		MORE THAN 25 PERCENT SLOPE				
5.5 or less	(3)	(3)	3	44.20	(2)	I
5.6 or more	Ridgetops and slopes	(3)	15	48.20	±8.48	I
	Flats	12 or less	1	35.80	(2)	I
		More than 12	3	49.59	(2)	I

1 *Area classes and their application are discussed in the section dealing with "Silvicultural Prescriptions" starting on page 8.*
2 *Number of plots insufficient to compute a standard deviation.*
3 *Data were insufficient to determine the quantitative effects of these variables on light soils.*
4 *Although no plots were encountered with this combination of characteristics it was assumed that bedrock within 12 inches of the surface would affect this site adversely as it did where steeper slopes prevailed.*

season. This condition was the result of a permanent water table at or near the surface in three areas and a very impervious clay soil at the surface in the fourth area. These plots averaged more than 10 site index units lower than similar plots that were medium- to well-drained. Since the pattern was consistent, these plots were placed in a separate classification even though there were so few samples that a "t" test could not be applied. It was further assumed that a similar pattern would apply in all categories even though there were no samples in two of them.

Broken Terrain

Plots that were on or adjacent to slopes exceeding 10 percent and with elevation changes of 15 feet or more are included in table 2. The mean site index of these 47 plots was 51 feet or 7 units lower than those on level or rolling terrain. This difference is significant at the 99-percent level.

In broken terrain, plots with less than 5.6 percent silt-plus-clay in the first 6 inches of mineral soil averaged 6 site index units lower than those with 5.6 percent or more. Plots on or adjacent to slopes of 25 percent or less generally had higher site indices than those associated with steeper slopes. On very sandy soils this difference amounted to only 3 feet while it was 8 feet on heavier soils.

Where there was less than 5.6 percent silt-plus-clay in the first 6 inches of mineral soil, the plots' position relative to breaks in the topography had very little apparent effect. In the heavier soils slopes and ridgetops generally averaged lower than the edges of flat areas above or below slopes. Terrain position had less effect where slopes did not exceed 25 percent than it did where slopes were steeper. On one plot, bedrock was encountered within 12 inches of the surface. This plot had a site index of 36 compared with a mean of 50 for other comparable plots.

Out of 71 plots on which the total stand was tallied, 54 were found to be fully stocked, with 80 percent or more paper birch in the main stand. The data from these plots were utilized to construct harmonized curves of cordwood volume over age and site index. Volumes read from these curves were compared with yield tables presented by Kittredge and Gevorkiantz (1929) for the Lake States, Dana (1909) for the Northeast, and Plonski (1956) for Ontario. The tables by Plonski were converted to cordwood volume using a factor of 79 cubic feet per cord as suggested by Gevorkiantz and Olsen (1955).

This comparison showed that the average volume of the stands studied in northern Wisconsin is well below that shown by any of these authors. Yields in Ontario were the closest, with 40- to 60-year-old stands having approximately 25 percent higher yields than similar stands in northern Wisconsin. Because the data from Wisconsin represented a limited range of age and site index, data presented by Plonski (1956) were used to guide the extension of yield curves to include those ages and site indices that will have significance in the management of pure paper birch stands. The Canadian yield figures were reduced by 25 percent and matched graphically with the Wisconsin data. The end result was a series of harmonized curves based primarily on the data collected in northern Wisconsin, but extended slightly beyond the range of the data. The volumes shown in table 3 were taken directly from these curves.

TABLE 3. — *Average cordwood yields in fully stocked paper birch stands in northern Wisconsin*[1]
(Standard cords)

Age (years)	Site index, feet at 50 years		
	40	50	60
45	7.4	12.3	21.3
50	9.1	14.7	25.0
55	10.8	17.0	28.0
60	12.0	19.0	30.7

[1] *Volume includes the merchantable portion of the main stem of all trees to a 4-inch top d.i.b.*

In mixed stands and pure stands combined a much greater range of ages and site indices was encountered in northern Wisconsin. Therefore, it was possible to develop growth curves for individual trees to indicate the maximum size obtainable on various sites. The site index curves in figure 1 represent average height growth of dominant and codominant trees, and table 4 was taken from harmonized curves of d.b.h. over age and site index, based on sample tree measurements.

With the limited range of ages in the study area, it is practically impossible to determine the age at which pure stands of various site indices achieve maximum mean annual volume increment. Plonski's yield tables (1956) indicate that stands having site indices of 43 and 51 feet in Ontario reach this point at about 60 years. Since the stands sampled in northern Wisconsin exhibit similar growth patterns, it is probable that the maximum rotation for pulpwood production is about the same as it is in Ontario. Furthermore, Dana (1909) found that sprouting capacity was feeble or entirely lacking in trees more than 60 years old. Since stump sprouts are an important source of paper birch regeneration, the chance of maintaining birch as an important stand element is materially reduced if the rotation is extended much beyond this age.

TABLE 4. — *Average d.b.h. of dominant and codominant paper birch trees in pure and mixed stands in northern Wisconsin*
(In inches)

Age (years)	Site index, feet at 50 years		
	60	70	80
35	5.1	5.5	6.0
40	6.8	6.9	8.1
45	7.0	8.3	9.9
50	8.0	9.6	11.4
55	8.8	10.5	12.4
60	9.4	11.1	13.1
65	9.8	11.5	13.5
70	10.1	11.8	13.9
75	10.3	12.0	14.2
80	10.4	12.1	14.4

For veneer and saw log production, trees will have to be retained until they are close to physiological maturity. The age at maturity varies from tree to tree, but it is usually about 80 to 90 years. Harlow and Harrar (1941) state that paper birch

rarely attains an age of more than 80 years. Dana (1909), working in the Northeast, found that seedlings matured between 70 and 85 years and sprouts between 50 and 60 years. The difference between seedlings and sprouts was not apparent in northern Wisconsin, and there was little evidence of quality deterioration in trees up to 85 years old. The scattered older trees that were encountered had a large amount of defect in the form of butt rots, cracks, and seams.

SILVICULTURAL PRESCRIPTIONS •

Based on subjective observations of stand conditions and the results of cutting, it seems improbable that a fully stocked stand of birch regeneration will follow cutting on very many areas presently occupied by this species. In the majority of situations, existing paper birch stands will be replaced with mixed stands in which paper birch is a minor component. Where there is an understory, the replacement will be a natural consequence following liquidation of a paper birch overstory (fig. 2). Where there is no advanced regeneration, the area will have to be planted to assure continuous productivity.

In order to realize maximum return from existing stands the manner in which they are cut should be varied according to the growth potential of the area.

The variation within each of the categories shown in tables 1 and 2 is so large that they cannot be applied to small areas with a very high degree of precision. However, the classifications are ideally suited to the classification of manageable units of a forest property. Site variations that have a significant effect on site index can be evaluated in terms of the proportion of the total area affected. For example, where the terrain is generally level, there may be knolls or ridges with steep slopes. If these constitute an area that has a significant effect on the treatment of a unit, they can be segregated and considered as a separate unit. If the area affected is small it may be ignored or growth predictions and silvicultural prescriptions adjusted to compensate for the lower productivity on the steeper slopes.

Utilized in this manner, soil and topographic features become an integral part of stand classification at all stages of management planning and execution. Management surveys may be stratified on the basis of generalized knowledge of soil and topography. Soil and topographic maps may be used as an adjunct to cover-type maps to minimize the variability within cutting compartment boundaries. In applying silvicultural prescriptions, the forester may vary his procedures on the basis of soil and topography so as to realize maximum value productivity. The pertinent topographic features are easily evaluated on the ground, and a minimum of simple soil sampling will serve to classify soils.

Class I Areas

On very poor sites, paper birch will begin to deteriorate before it is large enough to meet the specifications for specialty products, saw logs, or veneer bolts. Redheart is likely to develop early on these sites, and its rate of development will exceed diameter increment before the trees are very large (Dana 1909). Thus the proportion of high-quality white wood in trees growing on poor sites is likely to be very small. These stands should be clear cut for pulpwood when they are 60 years old or before. If there is an understory that has more value than the birch itself, it might be desirable to speed up the conversion process by cutting the overstory earlier.

There is little justification for intermediate cuttings to improve growth in stands on Class I areas. Thinnings from above would remove the best growing stock before the stand had reached the culmination of mean annual increment. Thinning from below would rarely yield an operable volume of merchantable products unless the stand density were reduced below desirable levels. Light thinning from below seldom has any effect on final yield or length of rotation.

Class II Areas

Ordinarily stands on Class II areas should be managed about the same as those on Class I areas. However, Class II areas have a higher mean site index, and vigorous trees on these sites will be large enough at maturity to meet the specifications for specialty products. If there is a good market

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FIGURE 2. — A typical paper birch-balsam fir stand in northern Wisconsin. Balsam fir will eventually replace paper birch on this site.

for these products and stands are accessible, total value yield can be increased by making a light thinning from below when the stand is about 50 years old. An operable pulpwood cut can usually be made at this time without adversely affecting the residual birch. With the low-vigor trees out of the stand, the rotation age can be increased to about 70 years.

Class III Areas

Stands on Class III areas have the potential for producing a high proportion of saw logs and veneer bolts (see cover picture). Pure stands can be thinned for pulpwood at least once when they are about 40 to 50 years old. Thinning should usually be limited to suppressed and intermediate trees to avoid creating large openings in the crown canopy. Large-crowned trees should be cut only when their removal will not expose crop trees. When the stand is 80 to 90 years old it should be clear cut.

If there is a well developed understory, with some trees reaching into the lower part of the main

crown canopy, the birch could well be removed in a series of partial cuts, taking single trees or groups of trees. Stands converting to northern hardwoods lend themselves to this procedure especially well. The end result will be an uneven-aged stand which may contain a substantial proportion of large high-quality birch trees. Filip et al. (1960) found in the Northeast that paper birch in northern hardwood stands reached a maximum size of 16 inches d.b.h. Observations in northern Wisconsin indicate that a few individual trees may reach 20 inches d.b.h. before serious deterioration begins.

Maintenance of a closed crown canopy should be the major consideration in selecting trees to be removed in partial cuts. The least vigorous individuals should be removed first because redheart is likely to be proportionately greater in slow-growing trees than it is in vigorous individuals. Therefore most of the cutting will be from below. Trees in the upper crown canopy should be removed as soon as there is evidence of top-dying because this also indicates a high proportion of redheart (Campbell and Davidson 1941).

SUMMARY •

A study of paper birch in northern Wisconsin was undertaken to provide forest managers in the area with information on yield and site requirements. Site characteristics and the age and total height of dominant and codominant trees were recorded on 103 plots. Stand tallies were made on 71 plots, 54 of which were fully stocked with paper birch.

Terrain was one of the principal determinants of site quality of paper birch in the area that was sampled. The silt-plus-clay content in the first 6 inches of soil and surface drainage also had a major influence on paper birch growth. On sites with less than 10-percent slope or where steeper slopes did not result in elevation changes of more than 15 feet, the best soils were those that had mottling in the first 48 inches. Where the terrain was broken up by steep slopes that resulted in ridges or knolls more than 15 feet high, site index was related to slope percent and position in relation to breaks in the topography. The presence of bedrock within 12 inches of the surface had a detrimental effect on site quality in this kind of terrain.

The predictions of volume yield in pure stands were limited because the pure birch stands that were sampled did not represent the entire age and site index range for the species. In order to make predictions that would apply to those stands most likely to be managed for maximum volume production, yield tables developed in Canada (Plonski 1956) were used to complement the sample plot data. Maximum size attainable was considered a better measure of the potential on good sites. Consequently the average size of dominant and codominant paper birch in mixed and pure stands on good sites was calculated from sample tree data.

Preliminary suggestions for the management of paper birch stands were based on subjective observations made during the course of the study. Most of the existing stands in the area apparently were the result of fire, and it is unlikely that the type will be perpetuated on any extensive areas. Many paper birch stands are converting naturally to some other species, and others are being converted by artificial means. This appears to be the most certain method of maintaining continuous productivity of areas presently occupied by paper birch.

On the poorest sites paper birch should be clear cut for pulpwood when it is 60 years old or before. There is no justification for intermediate cuts in these stands. On some of the medium quality sites, there is an opportunity to extend the rotation to approximately 70 years and harvest some small bolts for specialty products along with pulpwood. On the best sites many trees will reach saw log and veneer bolt size in an 80-year rotation. Intermediate cuts can be made to salvage less vigorous trees as pulpwood and increase the growth rate of residual trees. It is essential, however, to maintain a fairly tight crown canopy for the best development of the paper birch.

In most paper birch stands that are converting naturally to northern hardwoods, the birch can be removed in a series of light partial cuts with marking based on the condition of the individual trees. The understory trees will close any gaps created in the crown canopy quite rapidly so that the residual birch will not be drastically exposed. The most vigorous trees can be retained in the stand until they reach 20 inches d.b.h.

LITERATURE CITED

Campbell, W. A., and Davidson, Ross W.
1941. Redheart of paper birch. Jour. Forestry 39: 63-65, illus.

Cooley, John H.
1958. Site index curves for paper birch in northern Wisconsin. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 541, 2 pp., illus.

Dana, S. T.
1909. Paper birch in the Northeast. U. S. Dept. Agr. Cir. 163, 37 pp., illus.

Filip, Stanley M., Marquis, David A., and Leak, William B.
1960. Development of old-growth northern hardwoods on Bartlett Experimental Forest — a 22-year record. U. S. Forest Serv., Northeast. Forest Expt. Sta., Sta. Paper 135, 7 pp., illus.

Gevorkiantz, S. R., and Olsen, L. P.
1955. Composite volume tables for timber and their application in the Lake States. U. S. Dept. Agr. Tech. Bul. 1104, 51 pp., illus.

Harlow, William M., and Harrar, Ellwood S.
1941. Textbook of dendrology. Ed. 2, 542 pp., illus. New York.

Hutnik, Russell J., and Cunningham, Frank E.
1960. Silvical characteristics of paper birch (*Betula papyrifera*). U. S. Forest Serv., Northeast. Forest Expt. Sta., Sta. Paper 141, 24 pp., illus.

Kittredge, Joseph, Jr., and Gevorkiantz, S. R.
1929. Forest possibilities of aspen lands in the Lake States. Univ. Minn. Agr. Expt. Sta. Tech. Bul. 60, 84 pp., illus.

Plonski, W. L.
1956. Normal yield tables for black spruce, jack pine, aspen and white birch in northern Ontario. Div. Timber Mangt., Ontario Dept. Lands and Forests, Rept. 24, 40 pp., illus.

SOME RECENT STATION PAPERS

LAKE STATES FOREST EXPERIMENT STATION

Forest Recreation in the Upper Great Lakes Area: Proceedings of a Seminar on Research Needs, May 11-13, 1961. Sta. Paper 89, 104 pp., illus. 1961.

Wisconsin's Forest Resources, by Robert N. Stone and Harry W. Thorne. Sta. Paper 90, 52 pp., illus. 1961.

Field Calibration of a Neutron-Scattering Soil Moisture Meter, by Richard S. Sartz and Willie R. Curtis. Sta. Paper 91, 15 pp., illus. 1961.

Growing White Pine in the Lake States to Avoid Blister Rust, by Eugene P. Van Arsdel, Sta. Paper 92, 11 pp., illus. 1961.

Farm Lumber Consumption and Use Data: Needs and Methods of Estimating, by Allen L. Lundgren and Ronald I. Beazley. Sta. Paper 93, 20 pp., illus. 1961.

Pulpwood Production in Lake States Counties, 1960, by Arthur G. Horn, Sta. Paper 94, 28 pp., illus. 1962.

Small Private Forest Landowners in Michigan's Upper Peninsula — Characteristics, Ownership Attitudes, and Forestry Practices, by Dean N. Quinney. Sta. Paper 95, 20 pp., illus. 1962.

Contracting for Forest Aerial Photography in the United States, by Gene Avery and Merle P. Meyer. Sta. Paper 96, 37 pp., illus. 1962.

Three Pine Release Experiments in Northern Minnesota, by Robert E. Buckman and Allen L. Lundgren. Sta. Paper 97, 9 pp., illus. 1962.

Proceedings of the Fifth Lake States Forest Tree Improvement Conference. Sta. Paper 98, 42 pp. 1962.

Three Growing Stock Density Experiments in Minnesota Red Pine — A Progress Report, by Robert E. Buckman. Sta. Paper 99, 10 pp., illus. 1962.

Identification of Conifer Insects by Type of Tree Injury, Lake States, by H. J. MacAloney and D. C. Schmiege. Sta. Paper 100, 41 pp., illus. 1962.

Forest Insects and Diseases in the Northern Great Plains — A Survey, by Louis F. Wilson. Sta. Paper 101, 28 pp., illus. 1962.

Forest Plantations of Northern Lower Michigan, by Robert N. Stone and Clarence D. Chase. Sta. Paper 102, 31 pp., illus. 1962.

Private Forest Landownership in the Urban Fringe Area of Michigan, by Con H. Schallau. Sta. Paper 103, 17 pp., illus. 1962.

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